

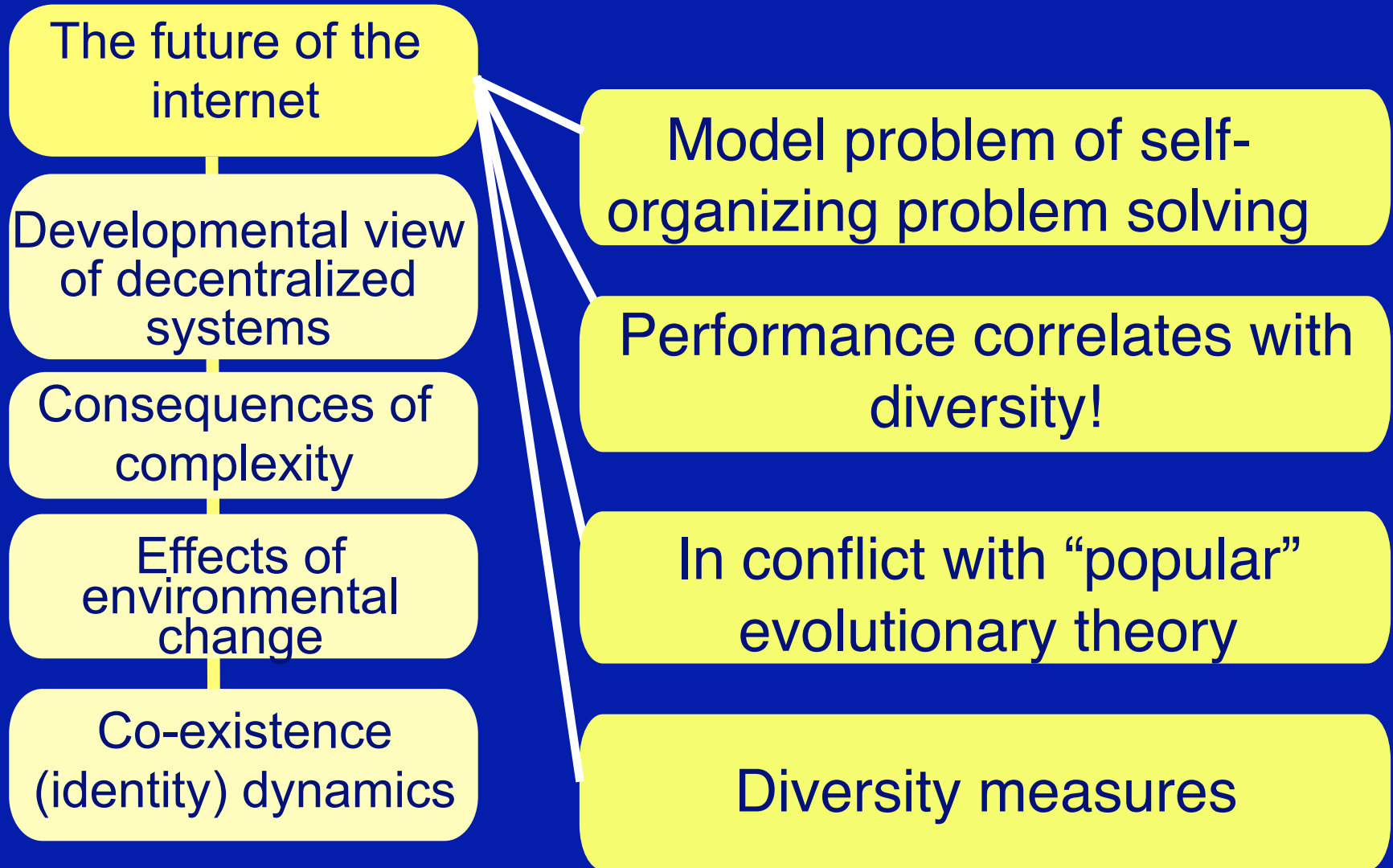
Development of Collective Structure & Its Response to Environmental Change

“Only dead fish swim with the stream”

Norman L. Johnson

Theoretical Division
Los Alamos National Laboratory

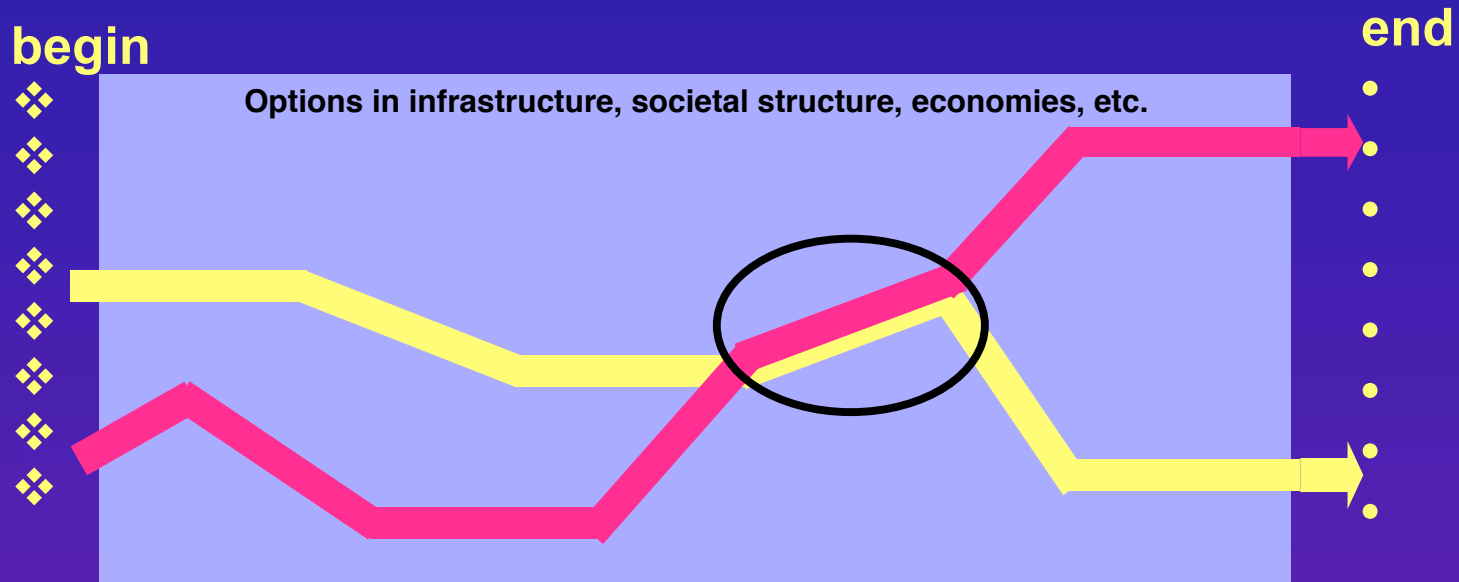
Roadmap



Collectives in complex environments

In complex domains:

- Beginning points differ
- End points differ
- But partial paths can overlay and find synergy



A Model for Collectives Solving *Hard* Problems

How can groups

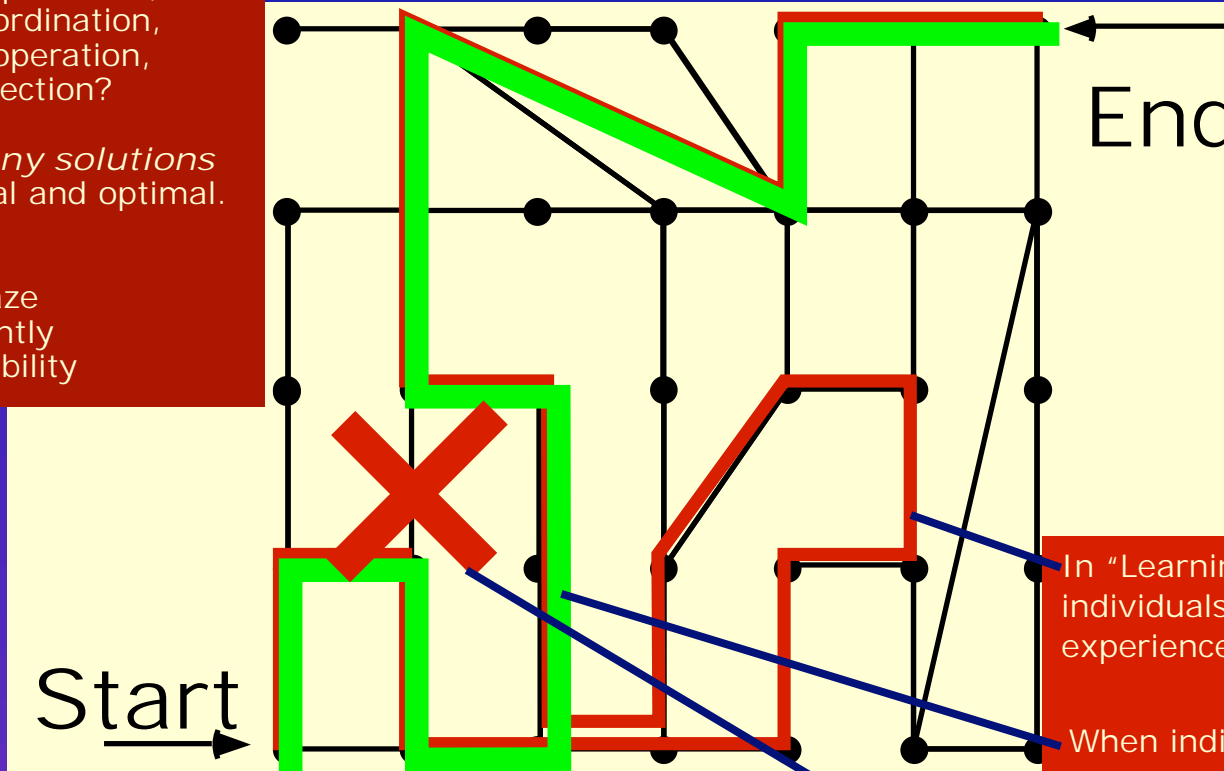
- > solve hard problems,
- > without coordination,
- > without cooperation,
- > without selection?

The Maze has many solutions

- > non-optimal and optimal.

Individuals

- > Solve a maze
- > Independently
- > Same capability



In "Learning" the maze, individuals create a diversity of experience.

When individuals solve the maze again, they eliminate "extra" loops

But because a global perspective is missing, they cannot shorten their path. This is where diversity helps.

Unfinished “extra” loops are completed by other agents

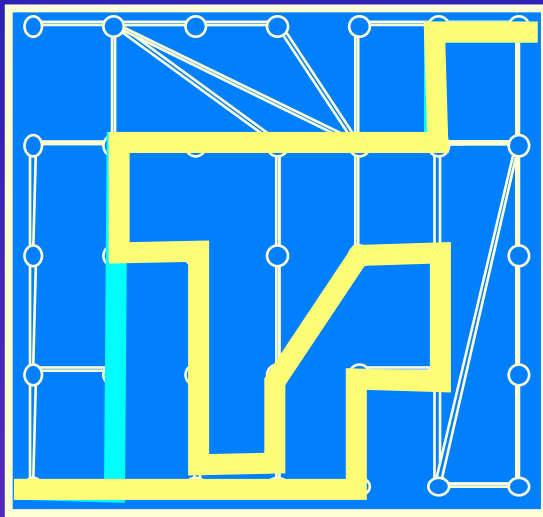


For ants: This is one method with diverse pheromone trails (with or without evaporation)

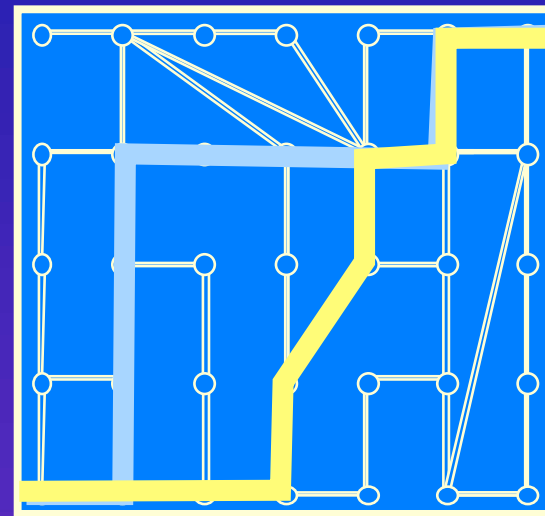
Noise and Robustness

Noise: Replace “valid” information with “false” information

An “expert” individual



A collective



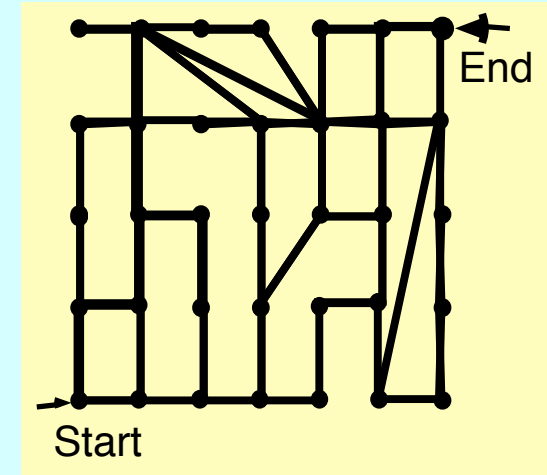
- Individuals are very sensitive to noise
10 steps become 21 steps
Due to lack of experience

- Collectives are insensitive
10 steps become 9 steps
Due to contingency from diversity

Research on Collective Self-Organization

The global emergent property is insensitive to details of the model, except:

- Groups of individuals using random searches show no collective advantage
Hence, individual and collective performance are coupled.



Found: Performance and robustness are highly correlated with Diversity

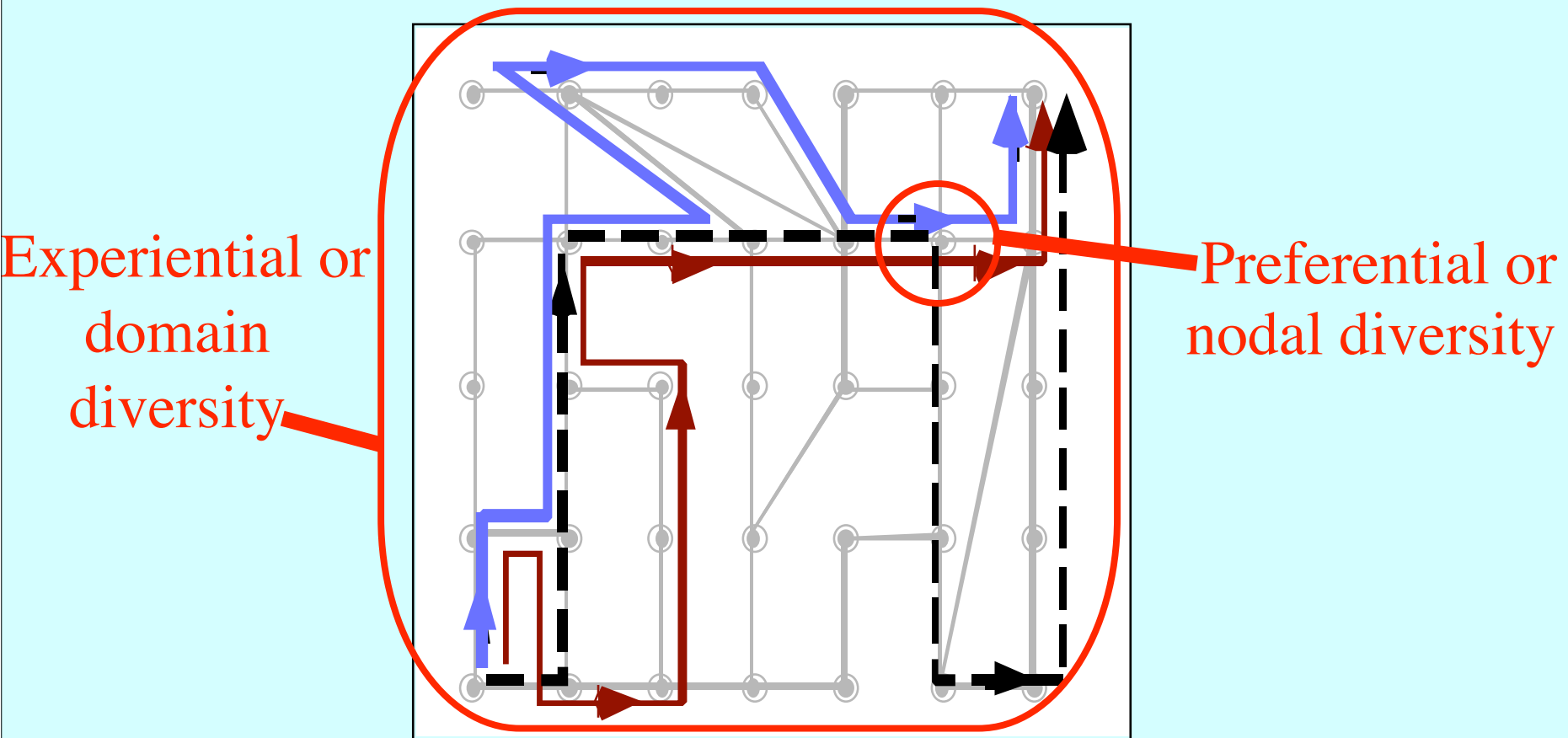
Diversity leads to better global solutions

Diversity leads to insensitivity to noise

Any selection from the diverse collective generally lowers global performance

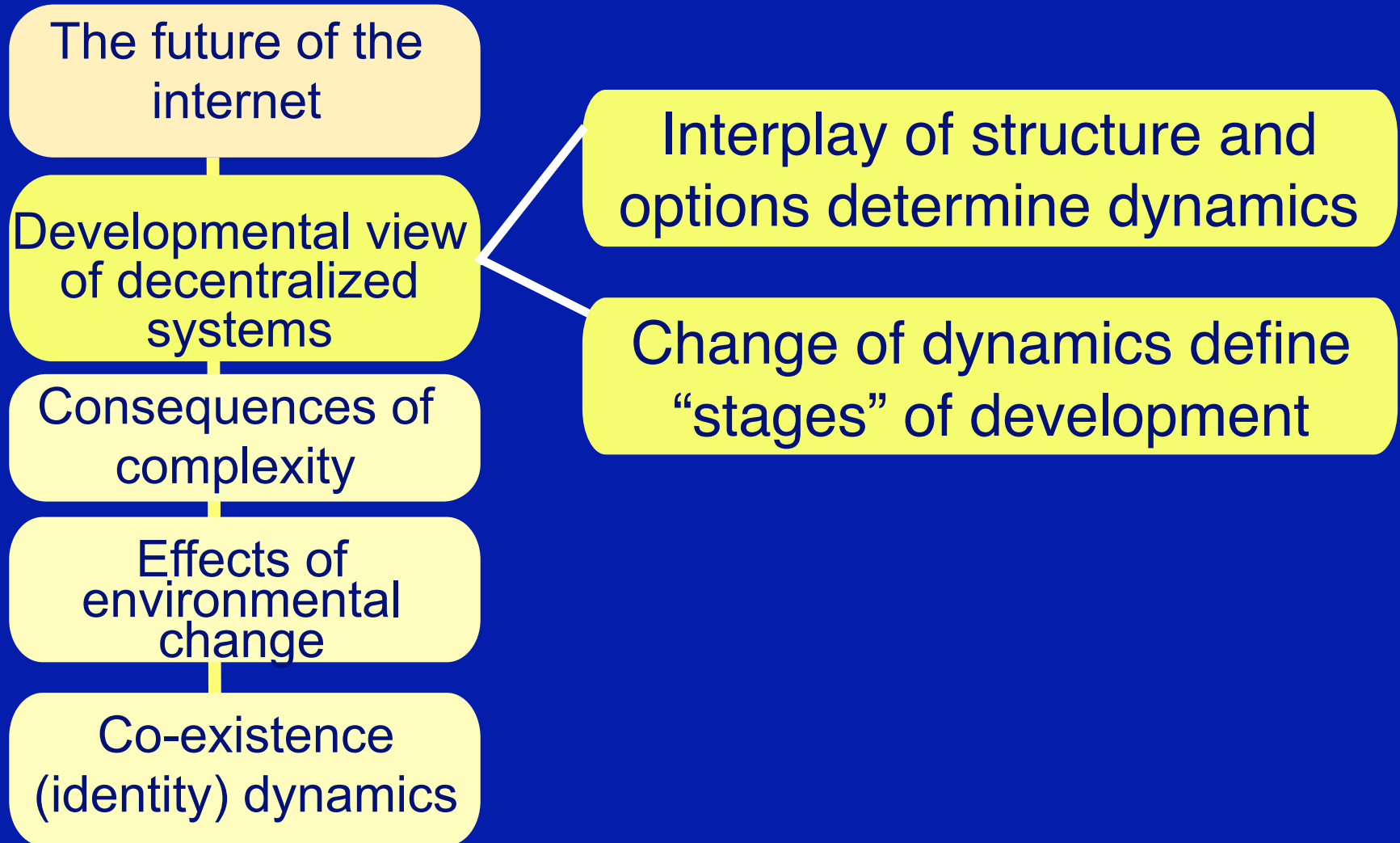
Sharing information speeds convergence (fewer individuals needed) to the optimal path, but at the price of diversity and robustness

Diversity Measure - a property of the collective

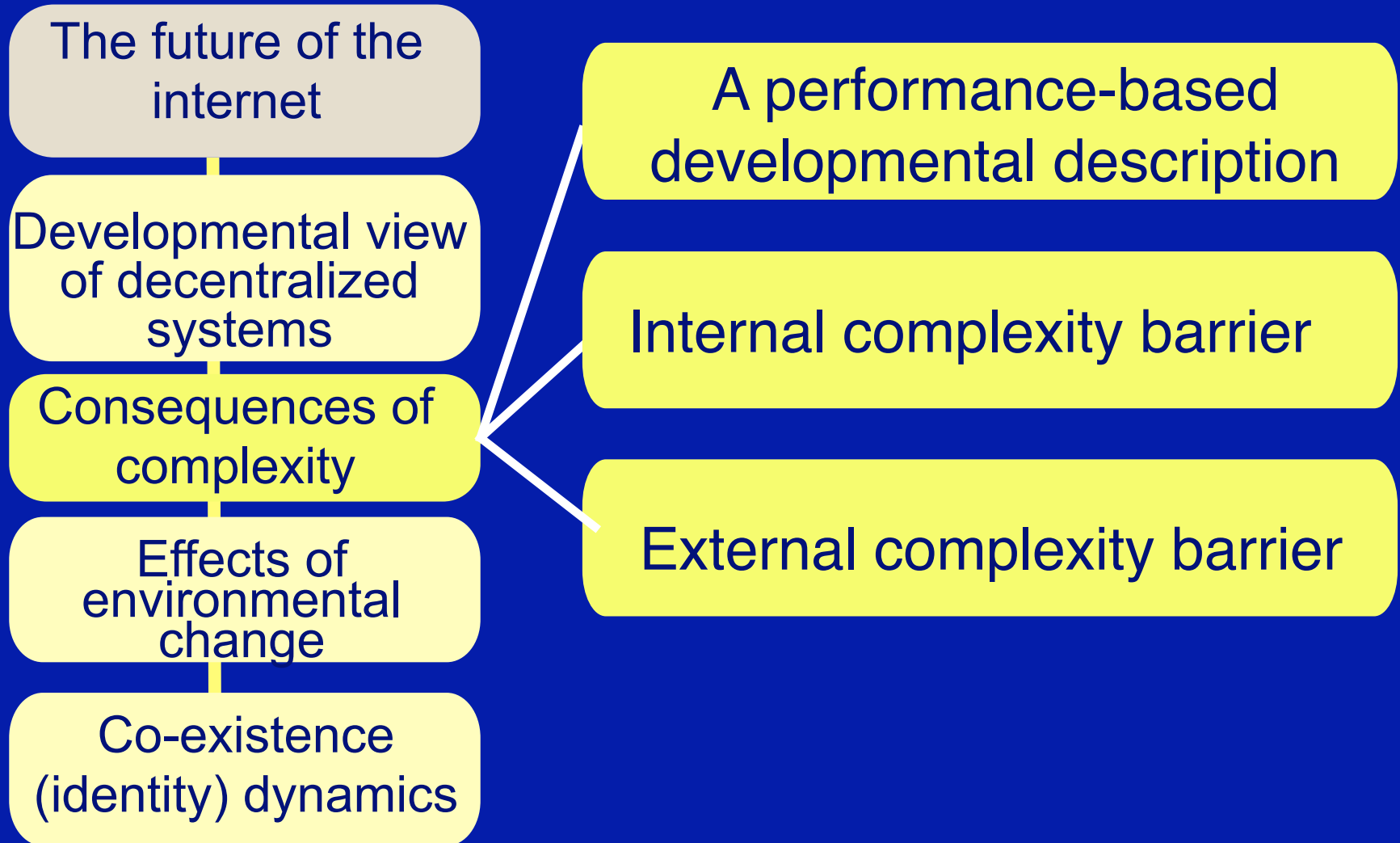


Best measure found to correlate with collective performance:
Sum of “Nodal diversity” of unique contributions to the collective

Roadmap



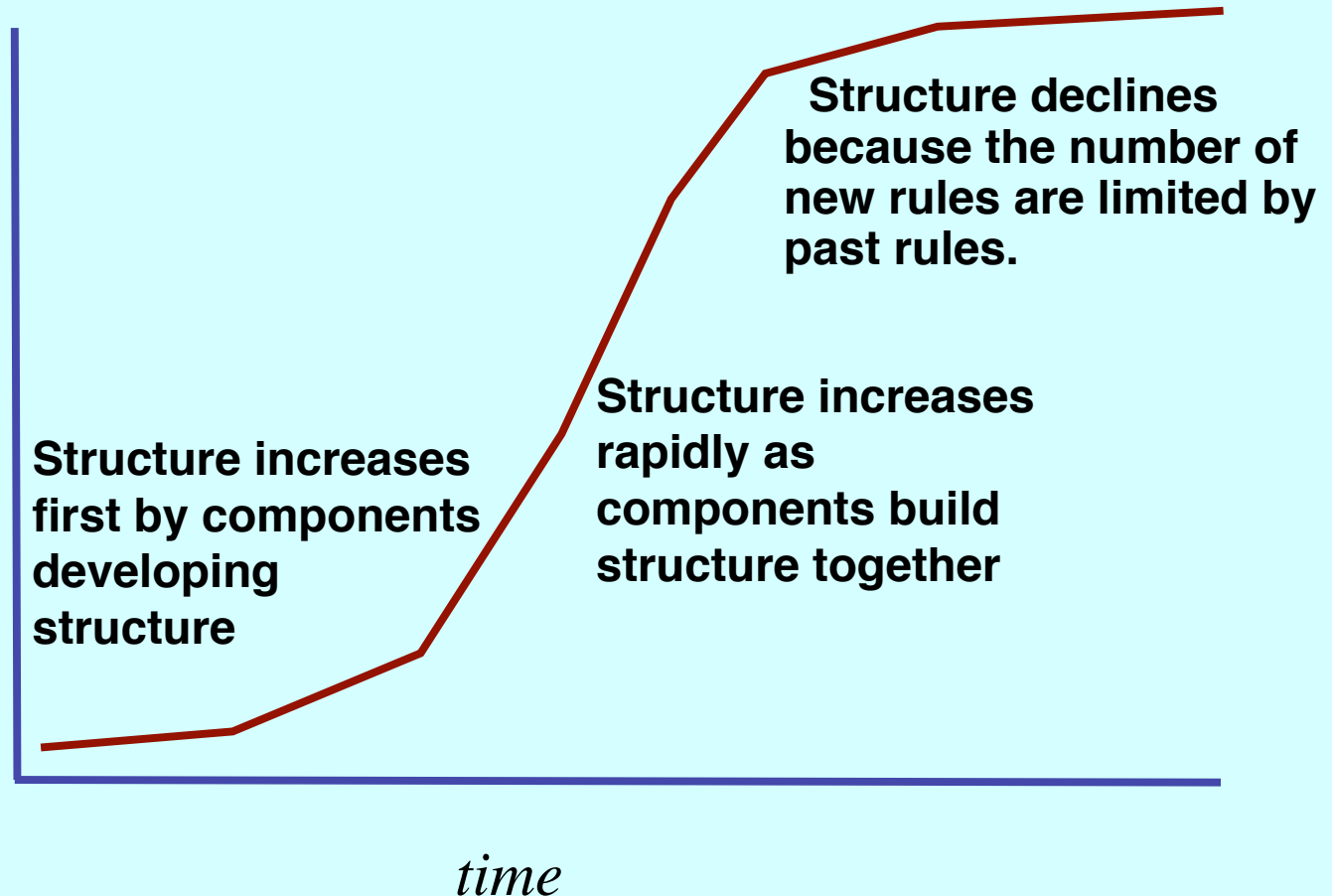
Roadmap



Structure in a system increases over time

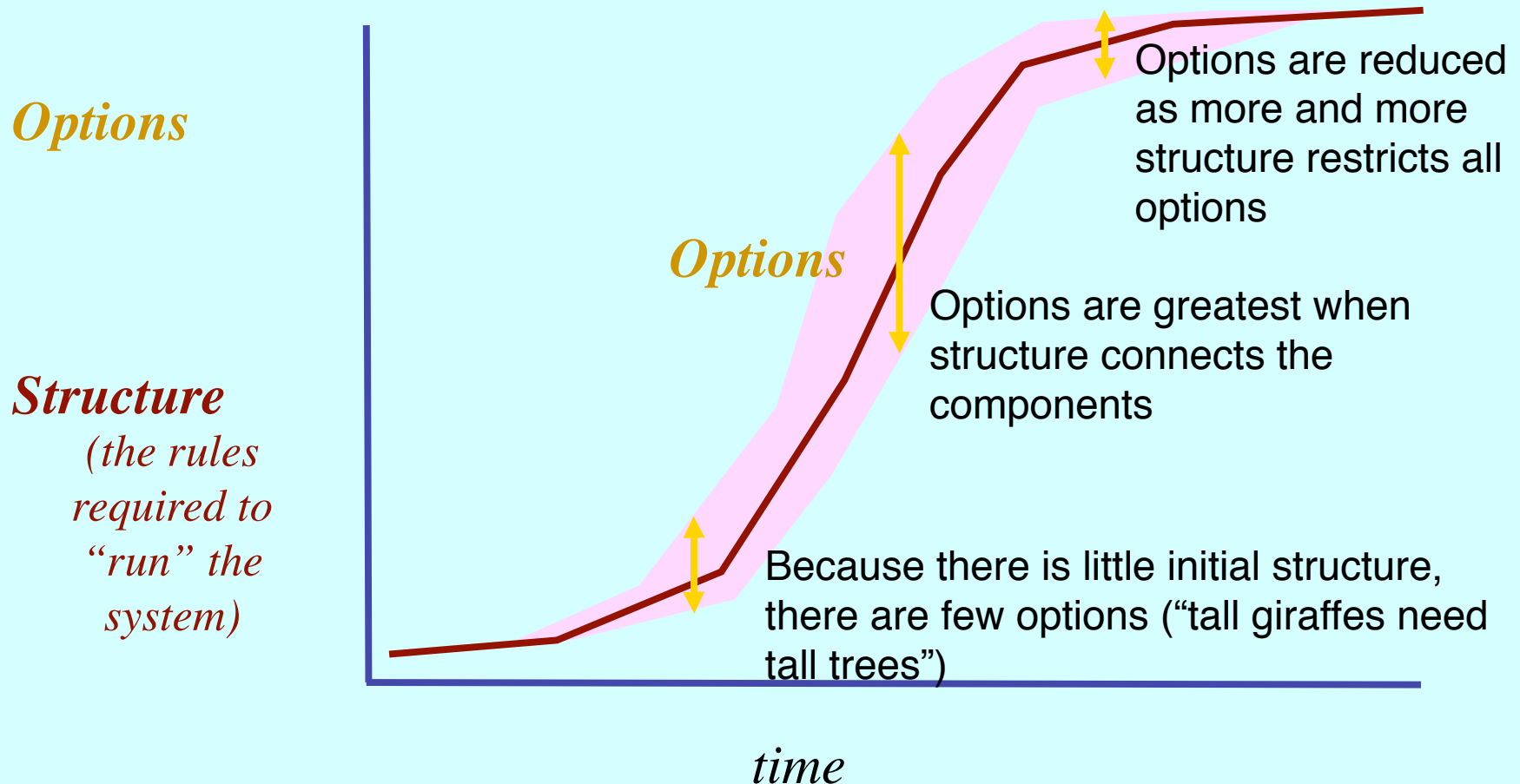
for decentralized, self-organizing collectives

Structure
*(the rules
required to
“run” the
system)*



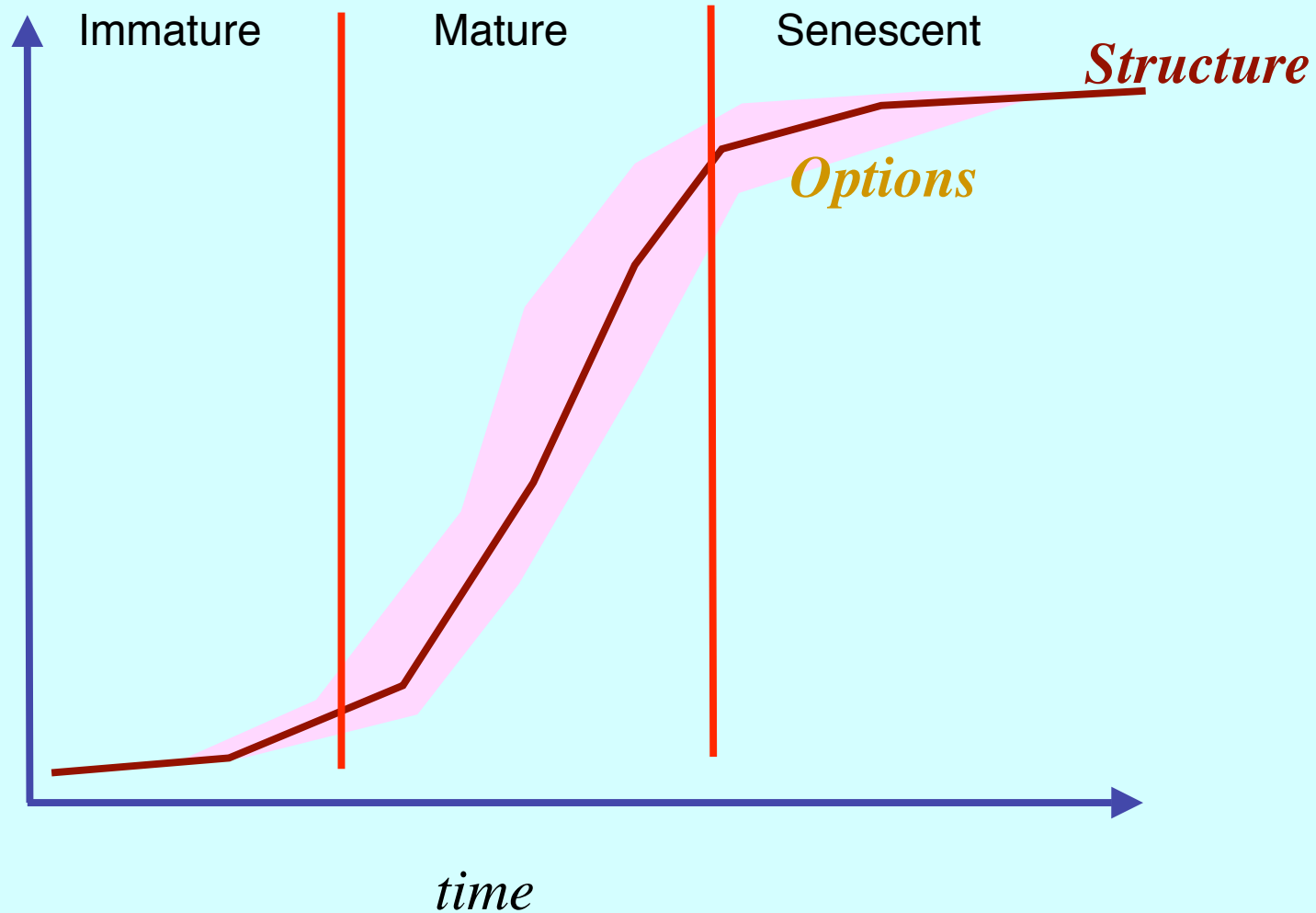
Options around Structure also change

Options are the free choices both created and limited by the structure (example: the rules of chess create an “environment” where many options are possible- while also limiting what choices are available)



These ideas are captured by researchers studying “infodynamics”

Stan Salthe's stages



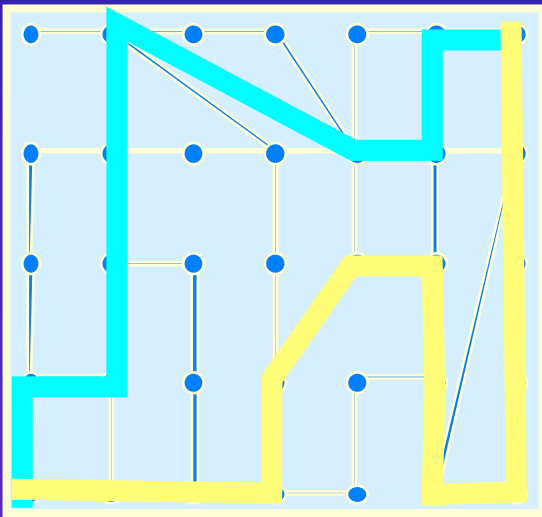
These ideas are captured by researchers studying “infodynamics”

Three stages of development

Dynamics are different depending on the stage of development

Formative

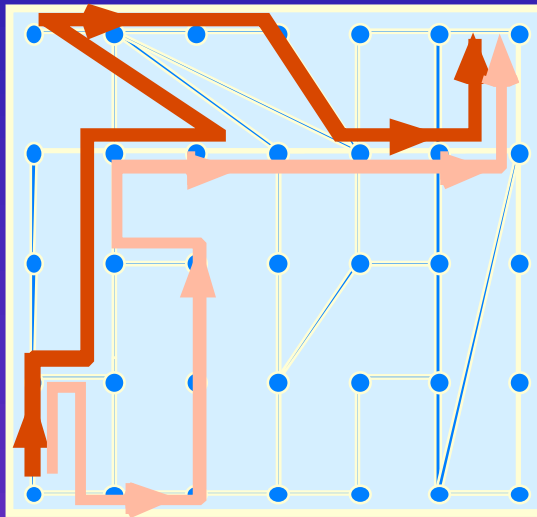
Individual development



Selection gives Agents capability, essential for the next stage.

Co-Operational

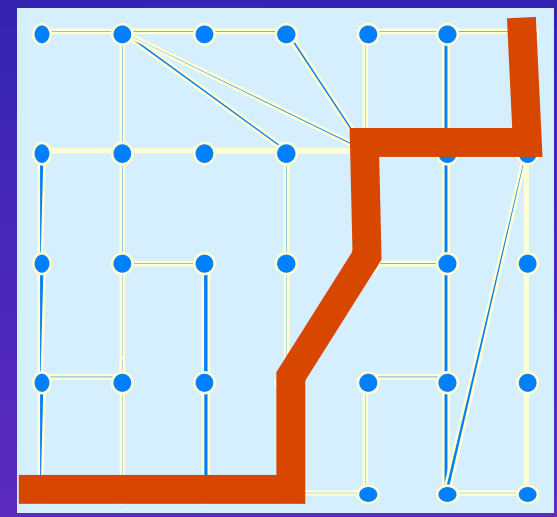
Collective improvement



Agents learn independently then share information during application

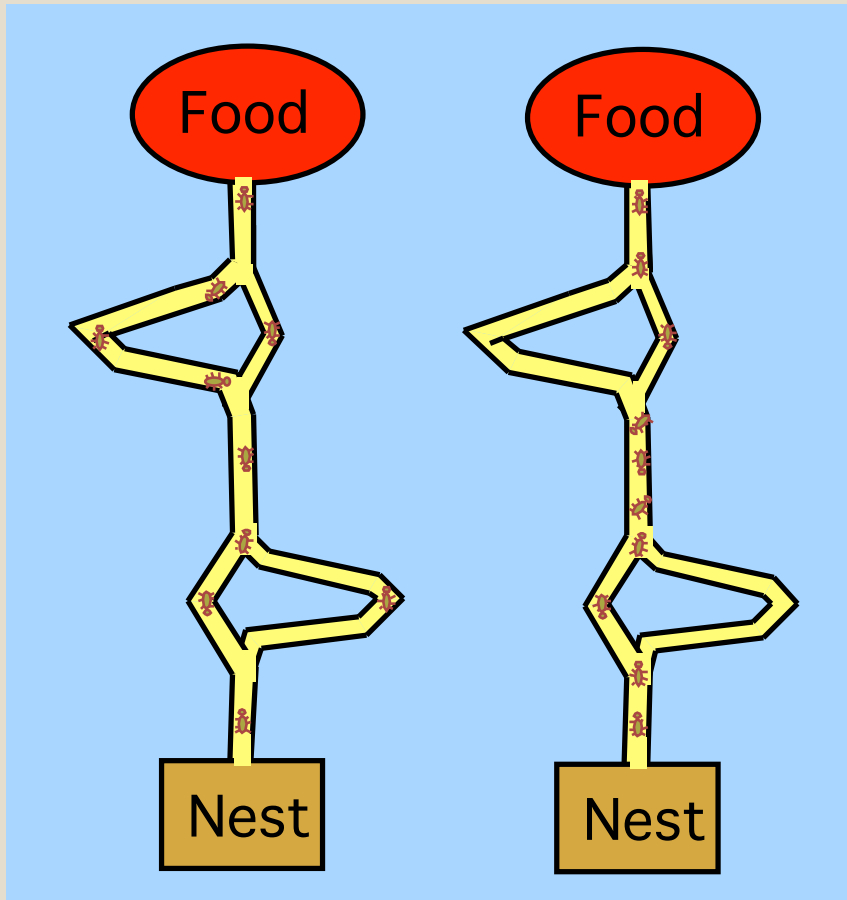
Condensed

System “refinement”



Agents share during learning in a stable environment

Dumb Collectives Solving “HARD” problems

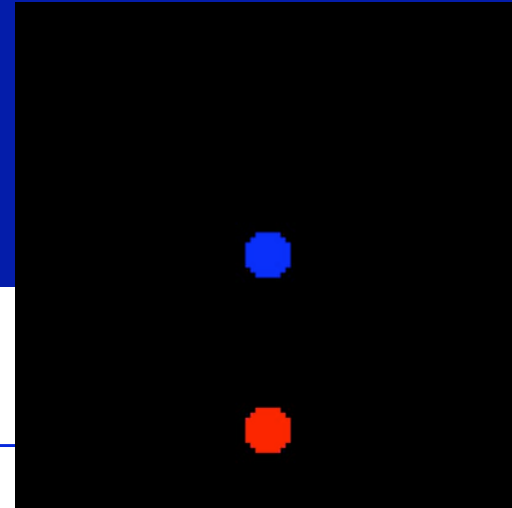
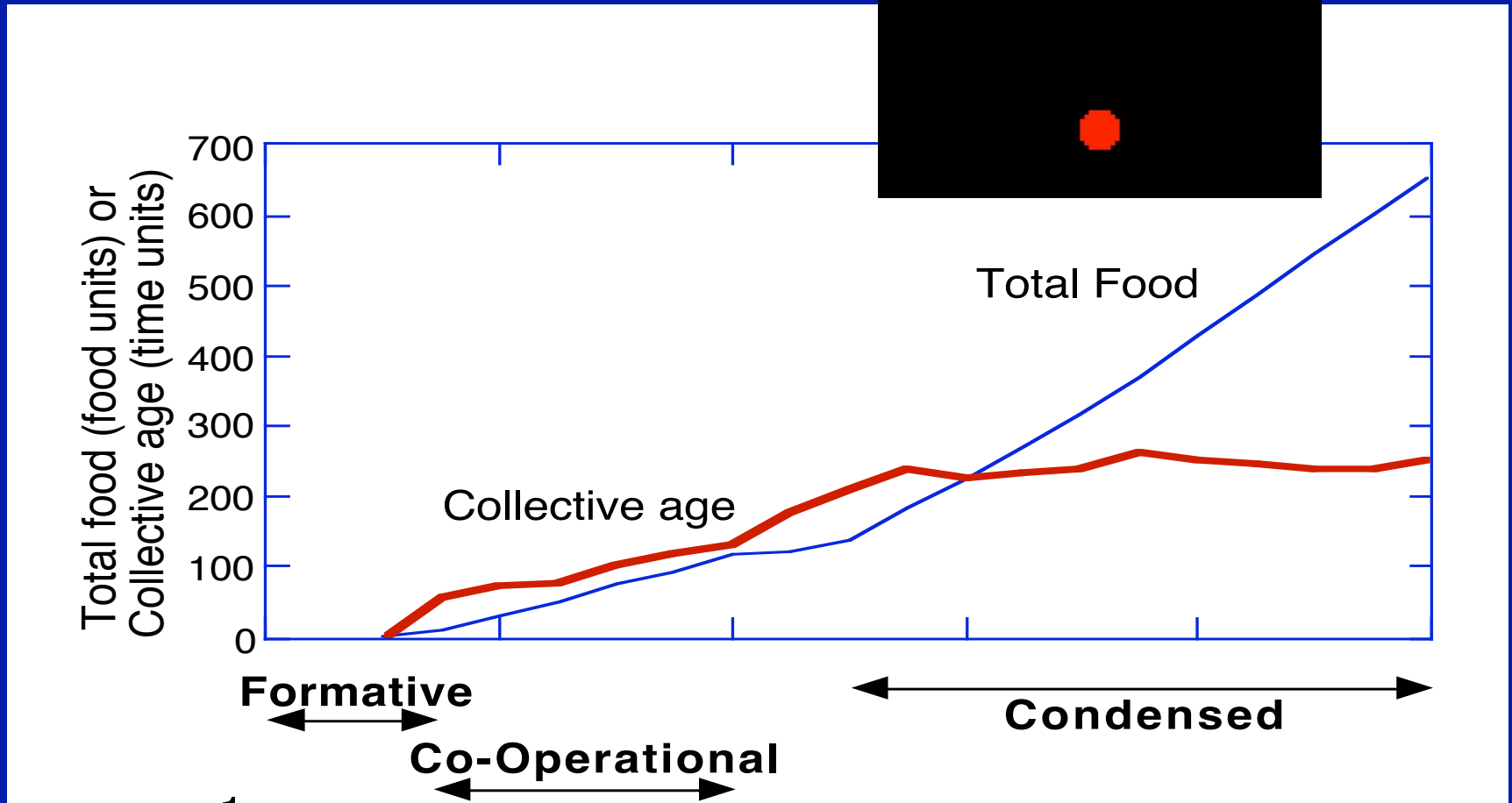


(Goss, et al. 1989)

- Individuals are “dumb,” chaotic, no global perspective
- No leaders or central coordination
- Only works for groups of diverse ants (and slime molds!!)

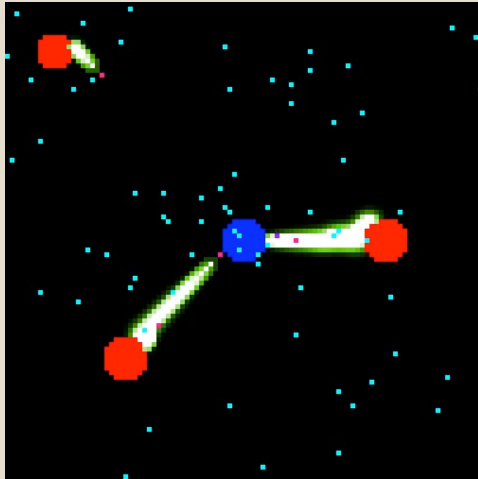
Three stages for a stable environment

Total Production versus time



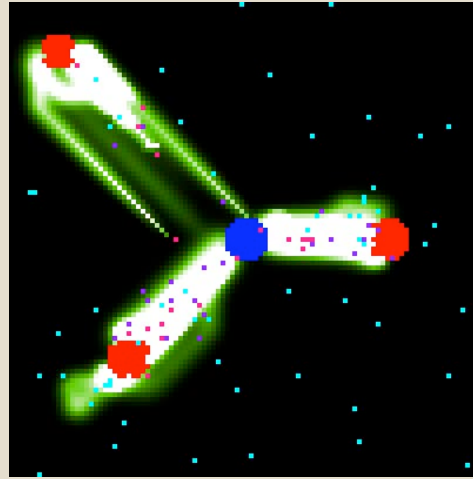
Stages of Development

Formative Forming definition



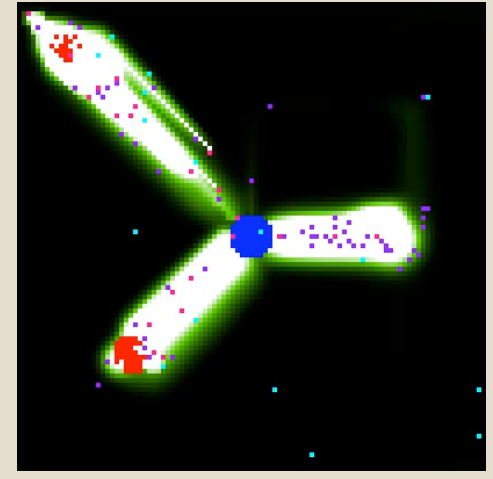
- Agent's path: Locally chaotic
- Productivity: Globally chaotic
- Low and evolving "structure" – no collective network
- Performance due to uncorrelated diverse contributions
- High diversity

Co-Operational Synergy of Individuals



- Locally chaotic
- Globally predictable
- Adaptive "structure" – robust collective network
- Performance from combination of diverse contributions
- High diversity

Condensed System optimization

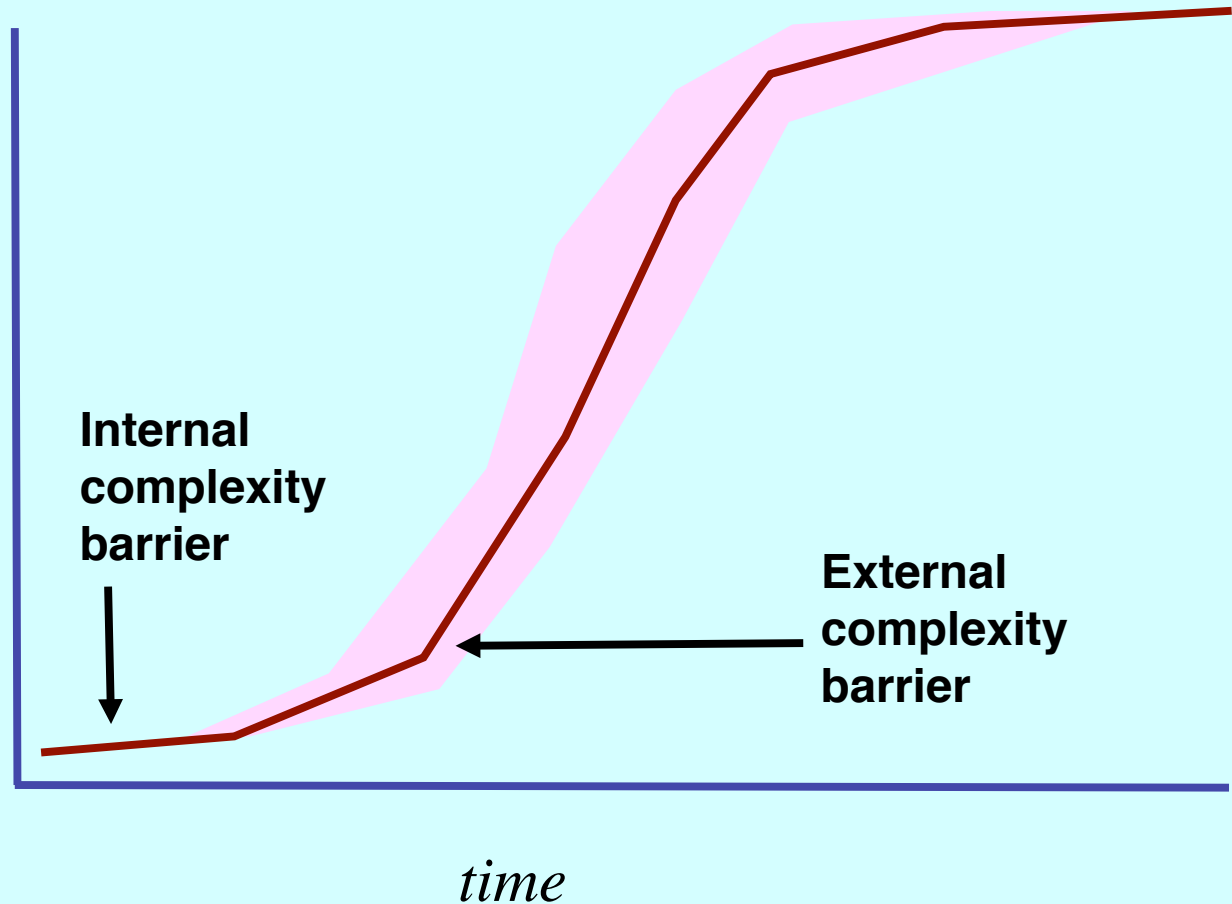


- Locally predictable (path)
- Globally predictable
- Unchanging "structure" – dominant collective network
- Performance due to optimized population (low diversity)
- Low diversity

Complexity Barriers

Options

Structure

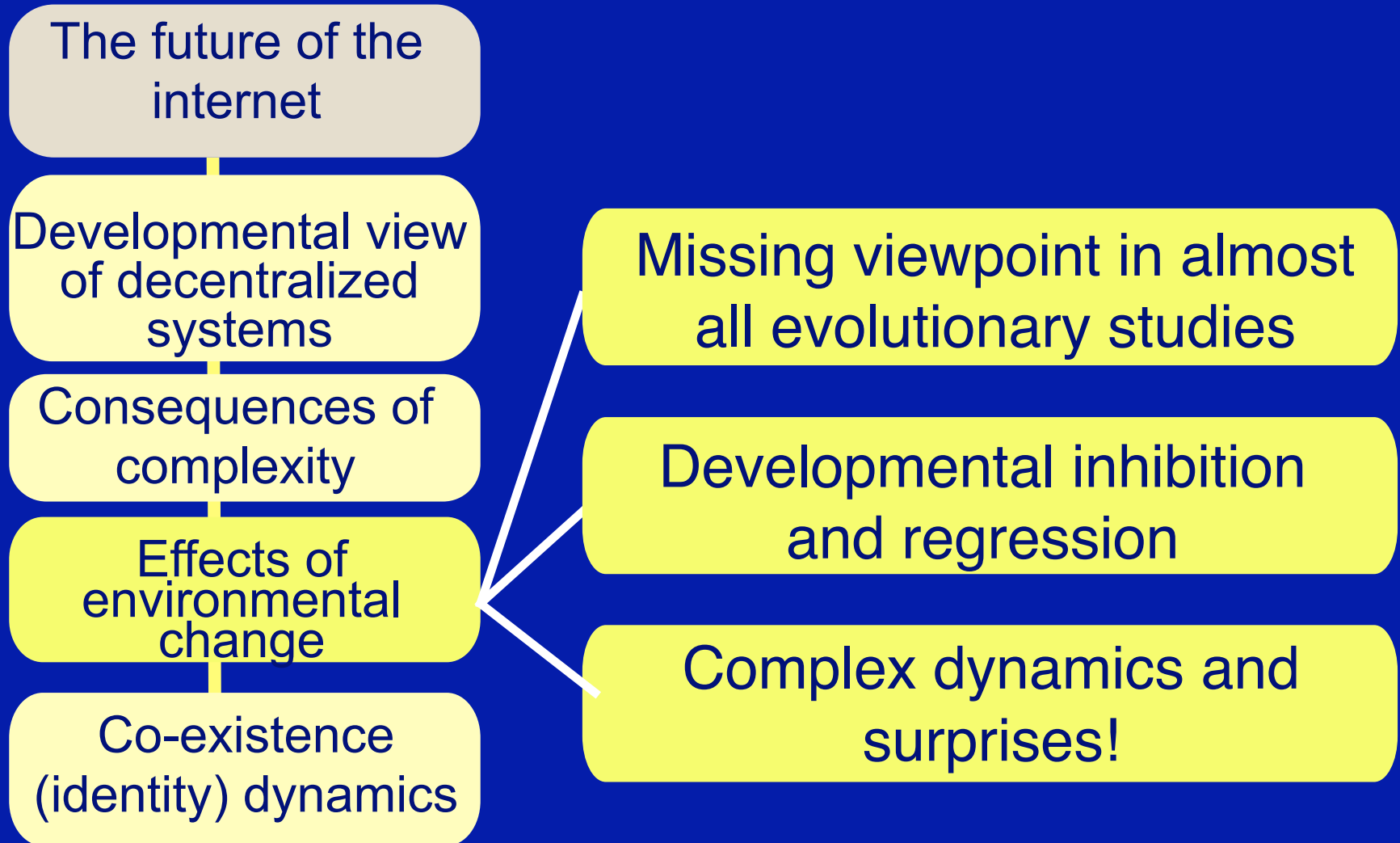


These ideas are captured by researchers studying “infodynamics”

Examples of the Complexity Barrier

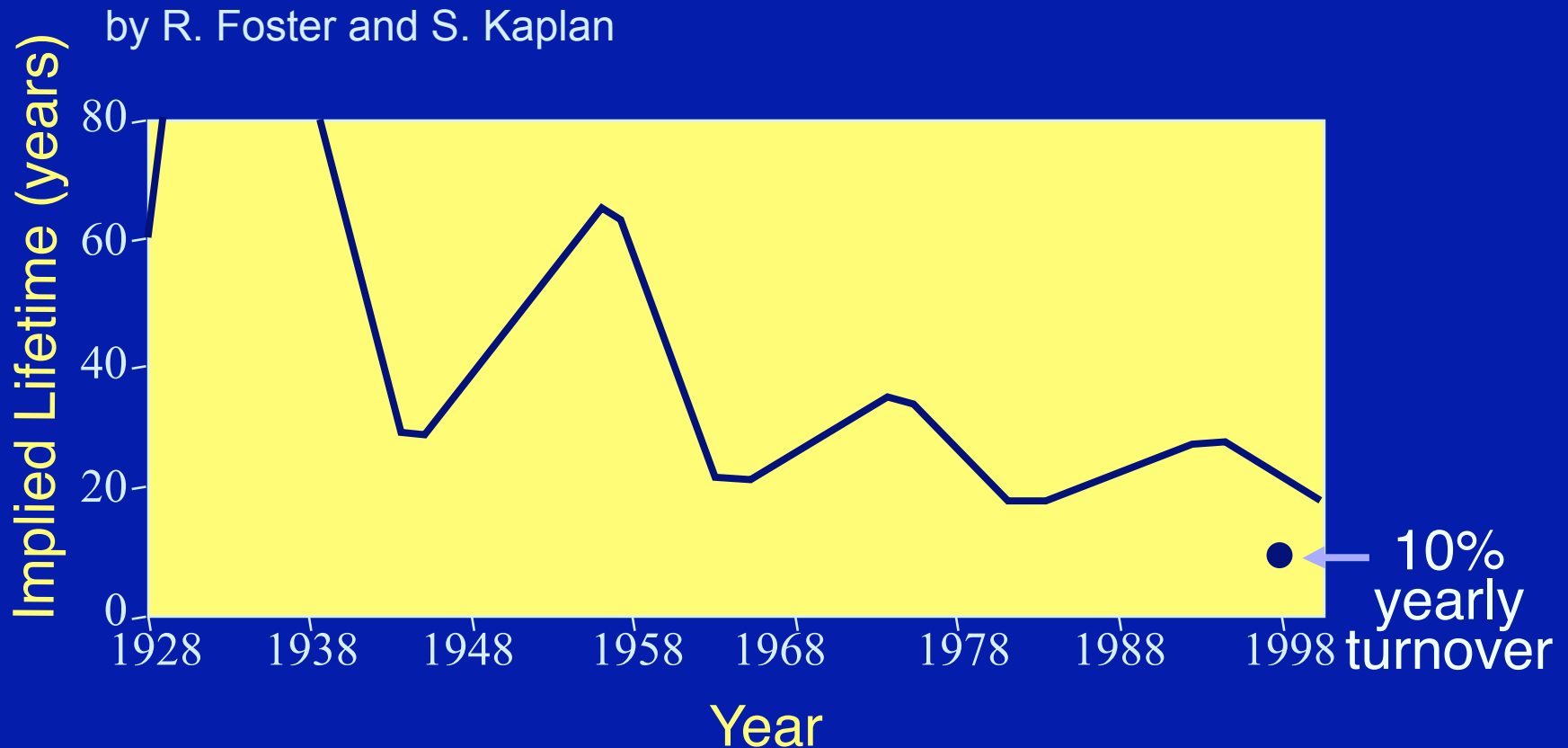
- When many genotypes lead to one phenotype, traits become independent of selection (Shipman)
- When complexity of the global problem increases, selection in genetic algorithms do not result in sustained improvement (Hart)
- Strong artificial selection on bacteria populations fail to pass on optimized performance (Swenson & Wilson)
- Modern experts only give answers, not rules

Roadmap

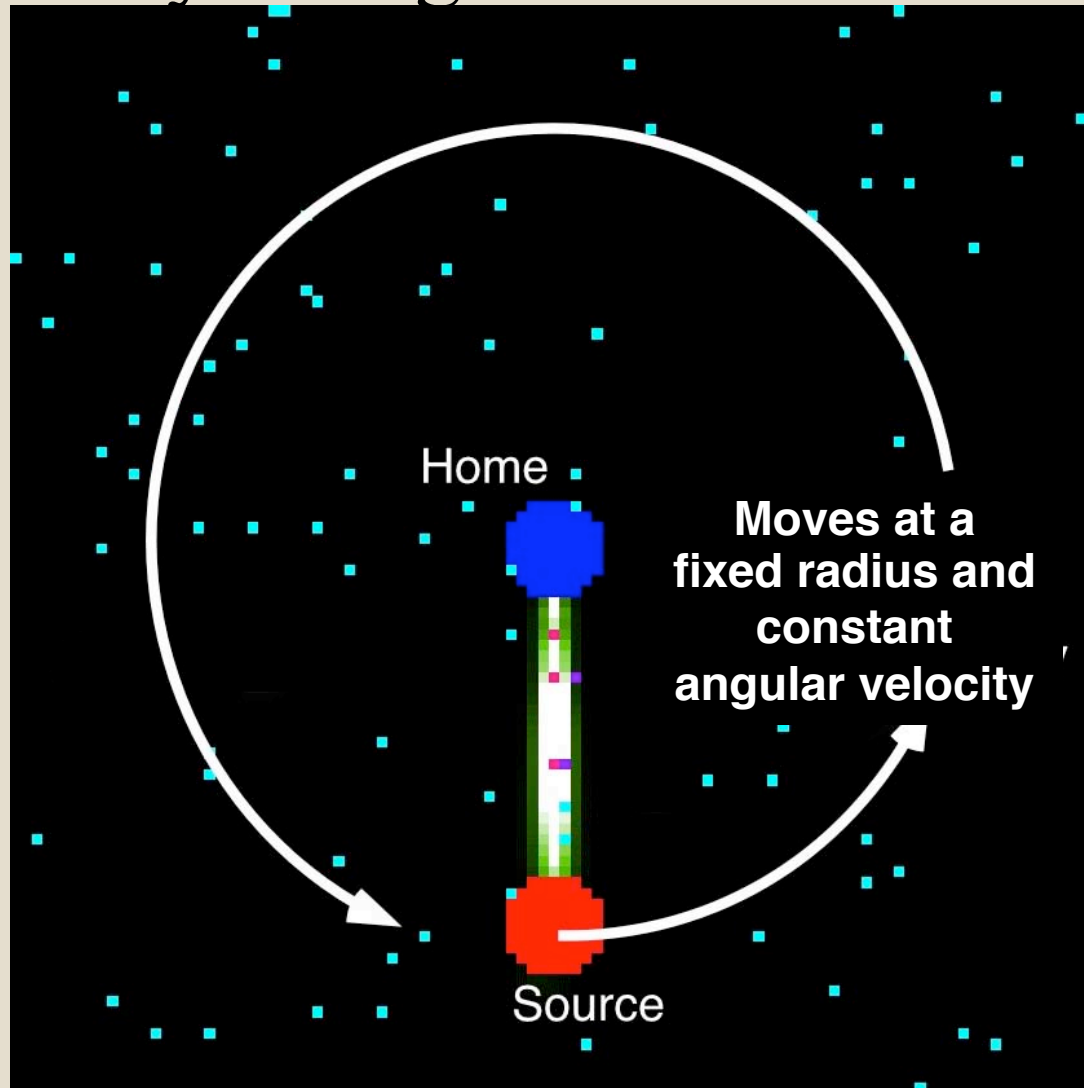


Why worry about change?

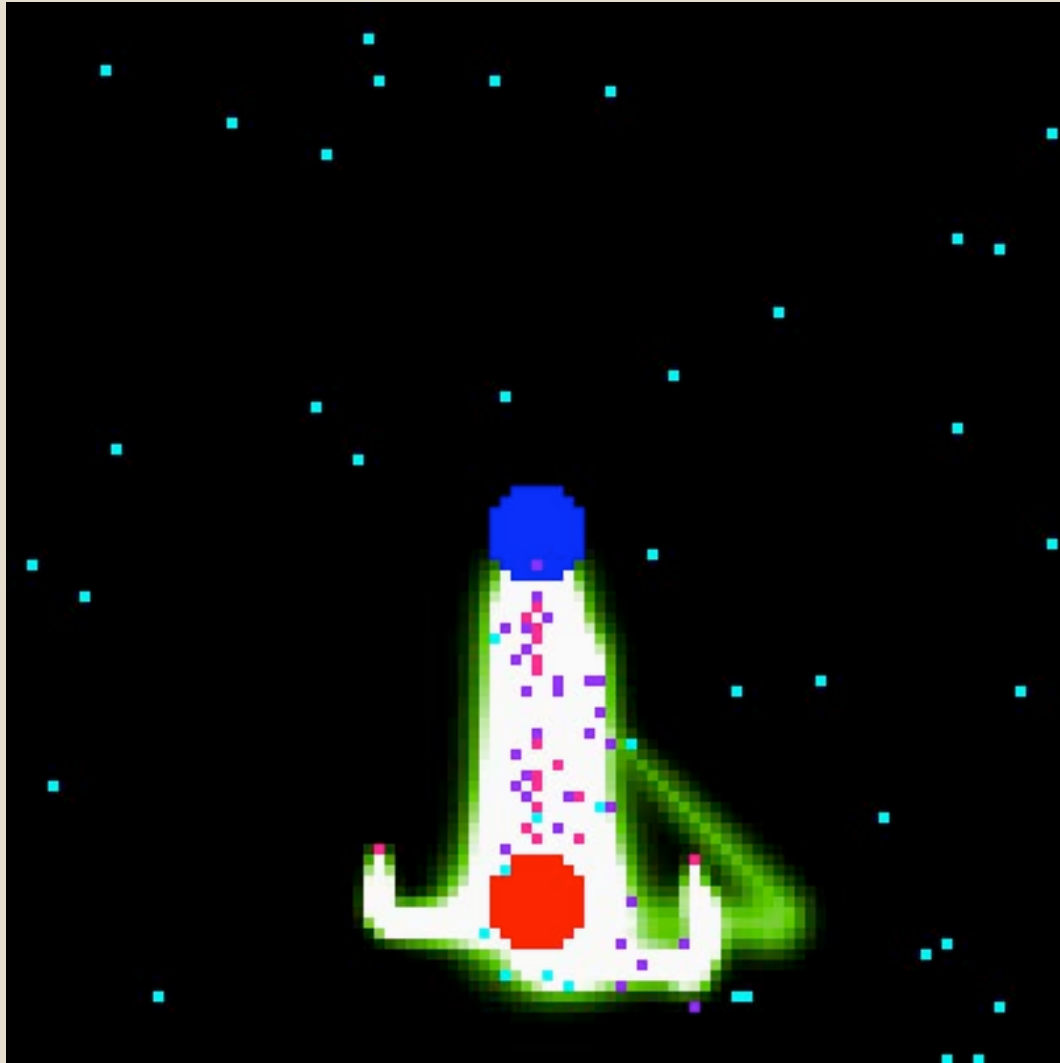
Average Lifetime of S&P 500 Companies From *Creative Destruction*



Try to quantify change and the herd effect



Slowly changing environment

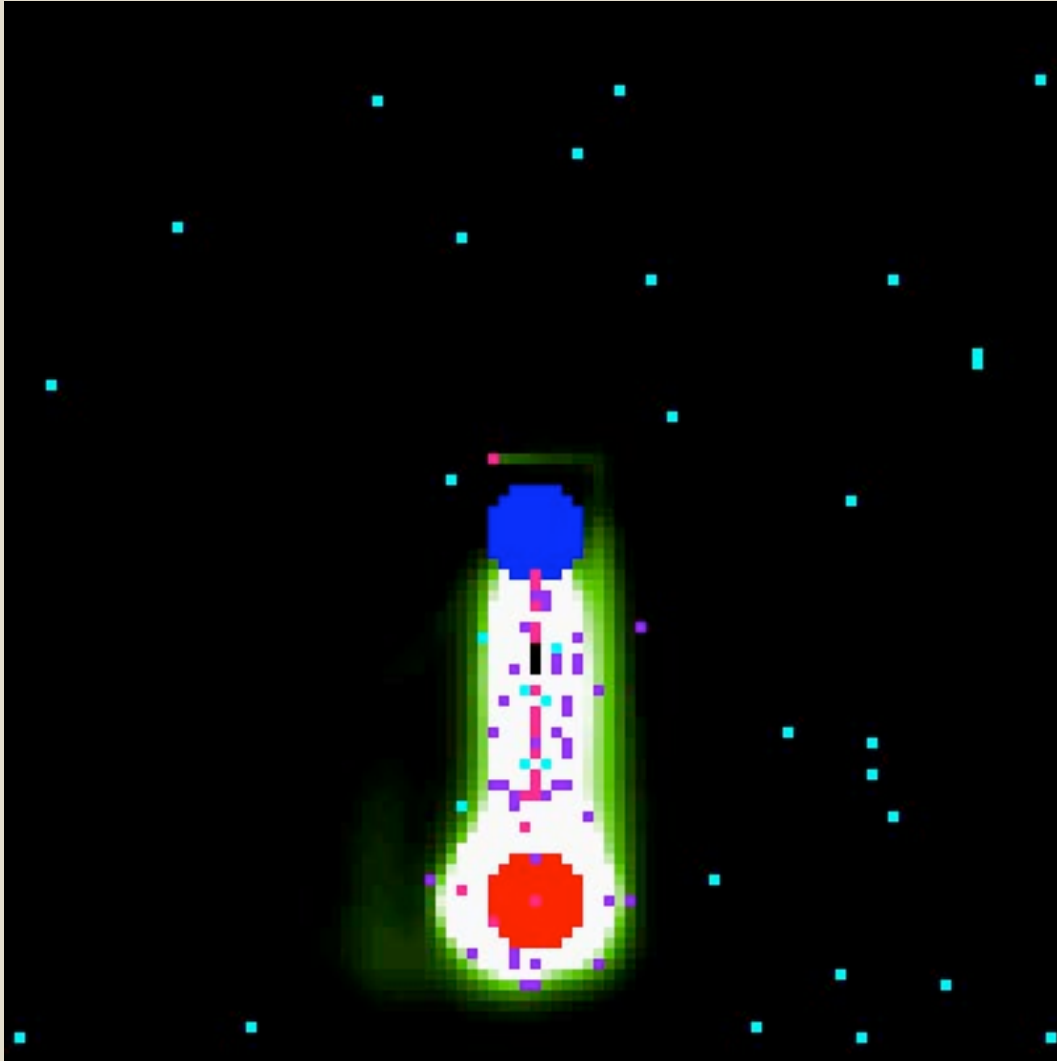


Productivity is only slightly less than an unchanging source

Herd effect allows for quick utilization of new resource location

Innovators become important (again) by sustaining optimal performance of the collective

Faster by 1/3

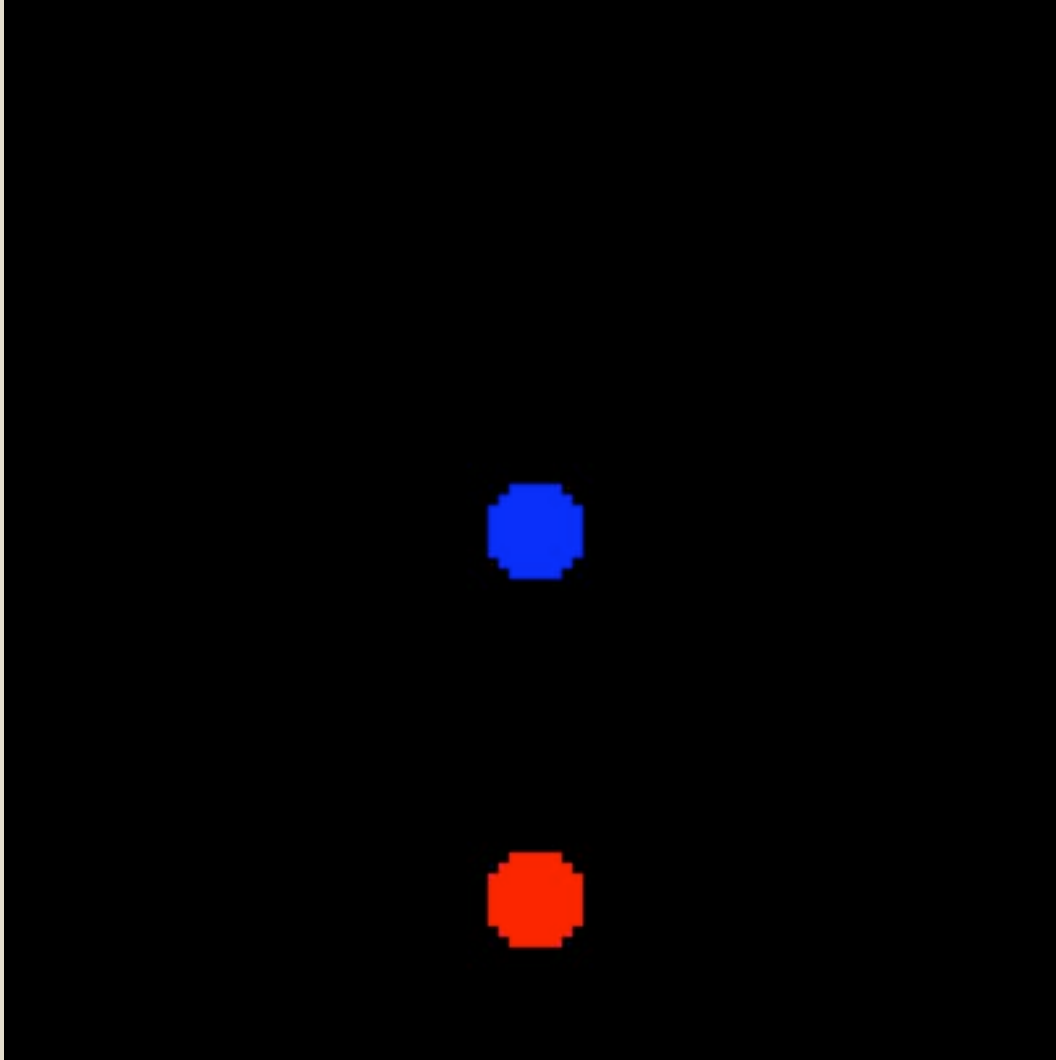


Boom and bust cycle

Instabilities lead to reversion to prior developmental stages.

Equal importance of herd effect and innovators

Rapidly changing environment

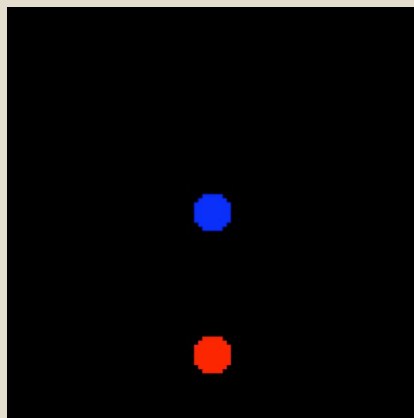
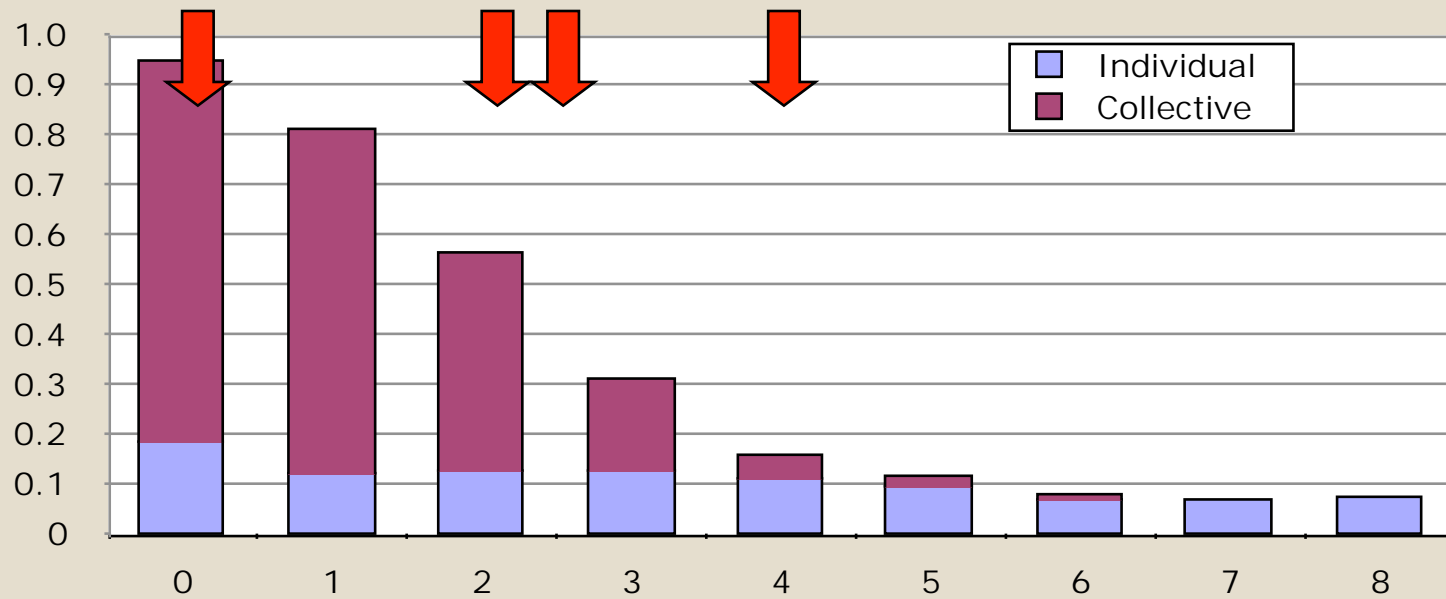


**Almost all
productivity is from
innovators**

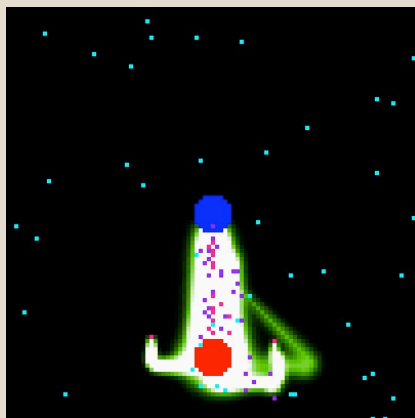
**The highly
productive
Condensed stage is
never realized**

**The herd effect can
actually degrade the
performance by
tying up resources**

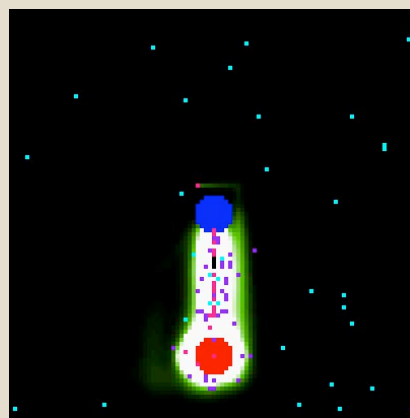
Food Production Rate



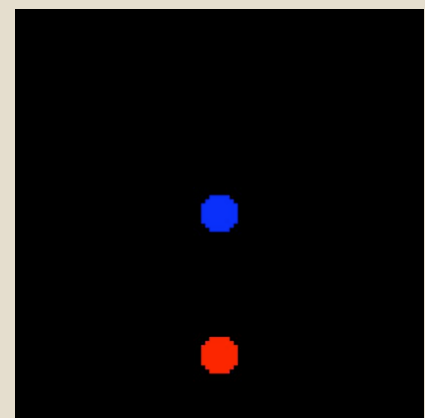
0



2



2.5



4

Structural Efficiency - a measure of the efficiency (or inefficiency) of the collective structure

$$\text{Structural Efficiency} = \frac{\text{Coll. Prod. rate (actual)} - \text{Coll. Prod. rate (neutral)}}{\text{Total Production rate}}$$

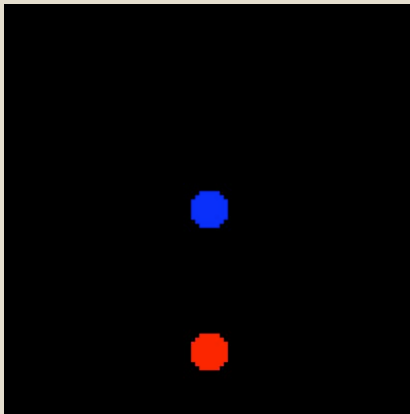
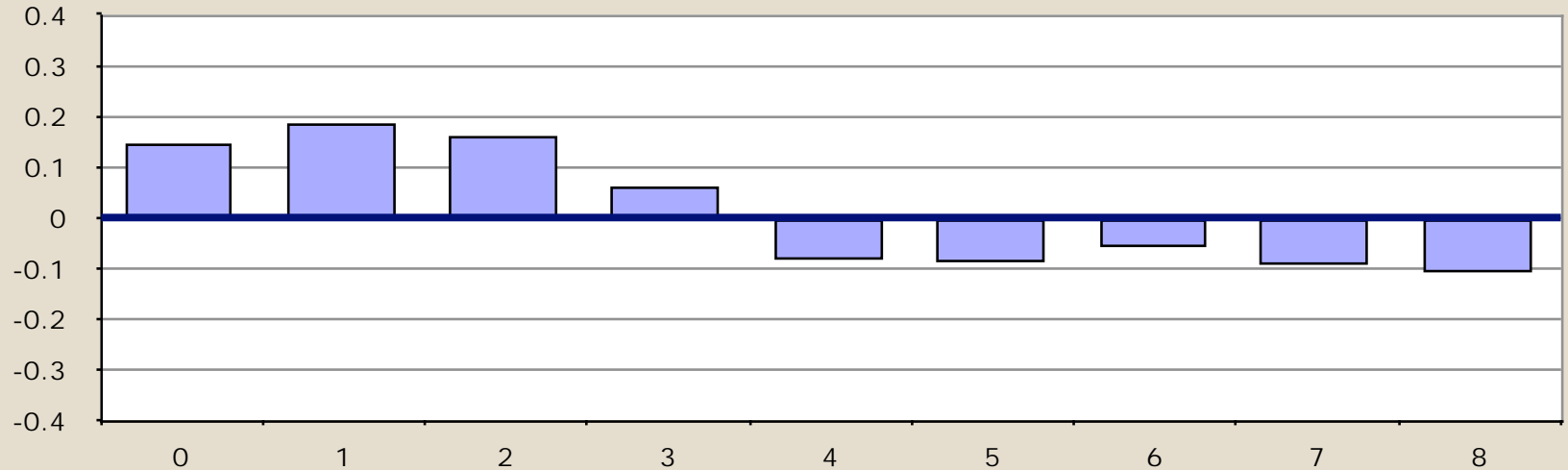
= excess food production by collective

Positive - the collective structure is beneficial

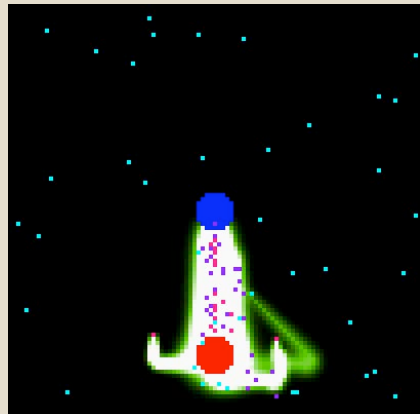
Negative - the collective structure is detrimental

Average Structural efficiency over many runs

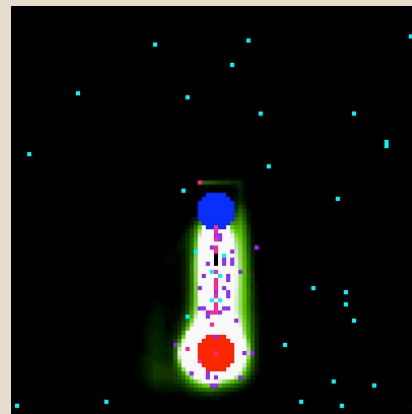
vs. Rate of change



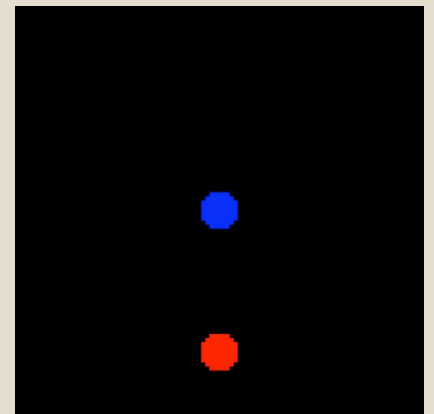
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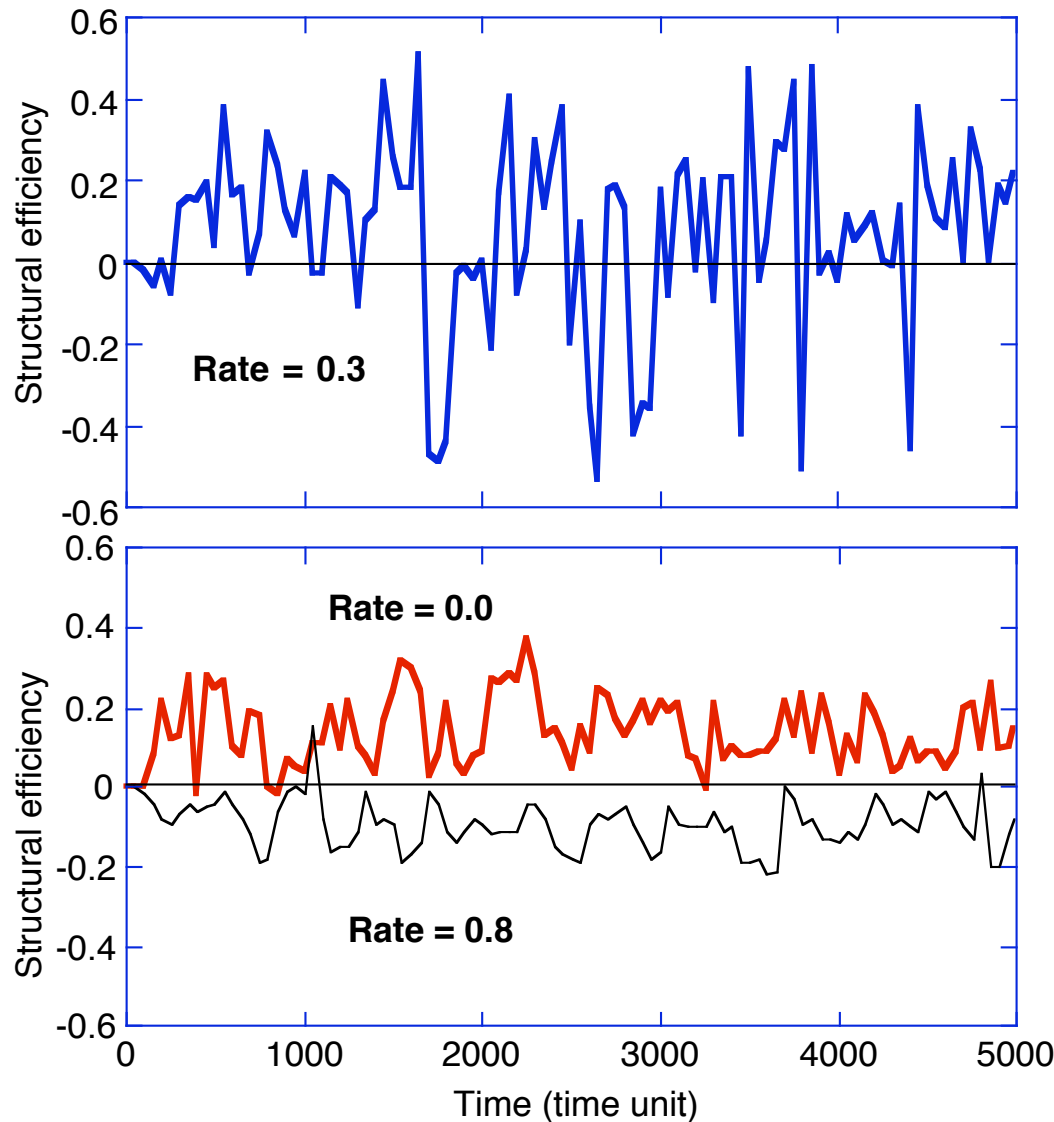


2.5



4

Time resolved Structural Efficiency - Boom and Bust























Lower average production -> crash avoidance

Greater minimums and maximums when compared to extreme rates!

Bust is proceeded by increased production

Collective Response to Rates of Change

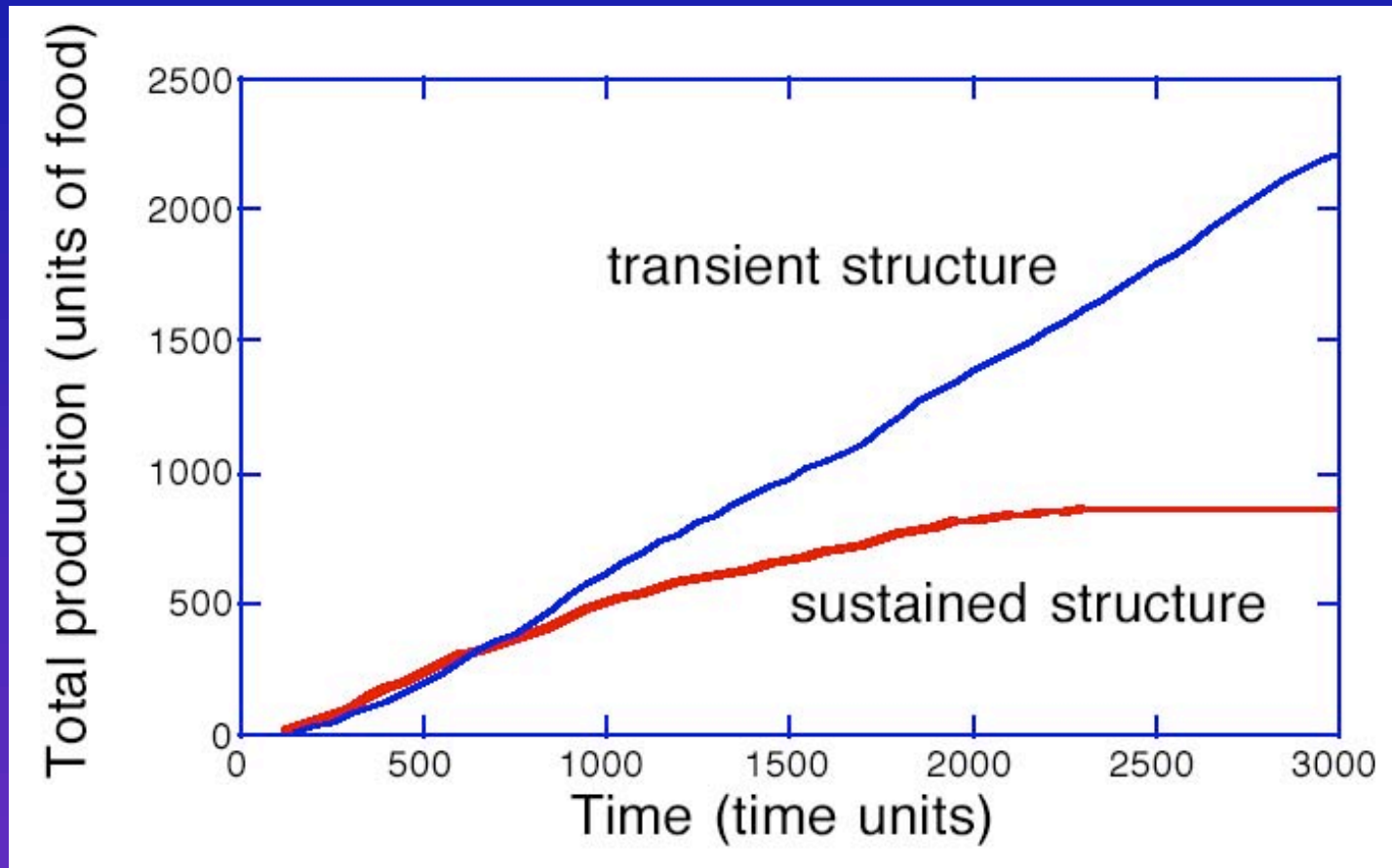
Stages in Development

	Unimpeded development	Innovators are essential	Collective actions lead to inefficiencies	Potential system-wide failure
Condensed (optimization of collective)				
Co-Operational (synergism from individuals)				
Formative (creation of individual features)				
Featureless				
	 Stable “no change”	 Change slower than collective response	 Change faster than collective response	 Change faster than individual response

Rate of Change

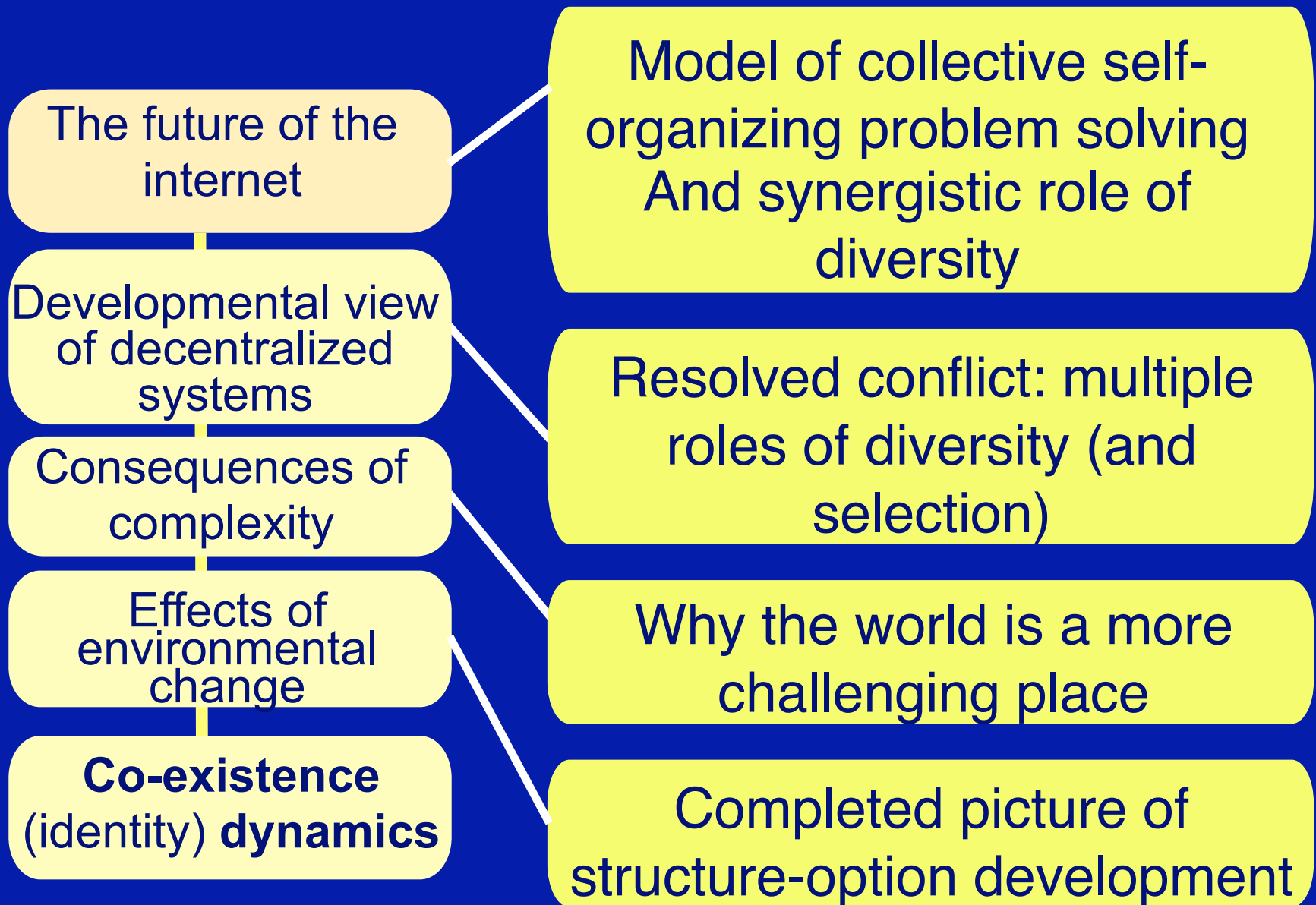
Transient versus Sustained Collective Structure

For the slowest rate of change examined - retain collective structure that is above a certain threshold



Expected for any system with collective mechanisms to sustain structure

Roadmap





Norman L. Johnson

Los Alamos

<http://ishi.lanl.gov>

Instructions for Life - Nobel Laureate *Tenzin Gyatso*

- Take into account that great love and great achievements involve great risk.
- Follow the three R's: Respect for self, Respect for others and Responsibility for all your actions.
- Remember that not getting what you want is sometimes a wonderful stroke of luck.
- Learn the rules so you know how to break them properly.
- Open your arms to change, but don't let go of your values.
- Share your knowledge. It's a way to achieve immortality.
- Once a year, go someplace you've never been before.
- Approach love and cooking with reckless abandon.